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Characterization and assessment of PAH content in spent char to be used for soil amendment and carbon sequestration

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Char is the solid by-product of biomass gasification, which is rich in recalcitrant carbon and has a good carbon sequestration potential if amended in soil as gasification biochar (GB). This may benefit the overall carbon balance of the process while improving soil quality [1-3]. At the same time, previous studies have shown the eligibility of GB as a substrate for producer gas upgrading through tar conversion [4,5]. This application would benefit the economy and the environmental impact of gasification. In this work, the properties of fresh GB (as received) and spent GB (used in gas treatment tests) have been investigated to establish if the material may still be suitable for soil application after being used for the treatment of tar-rich producer gas.

Concept and test method

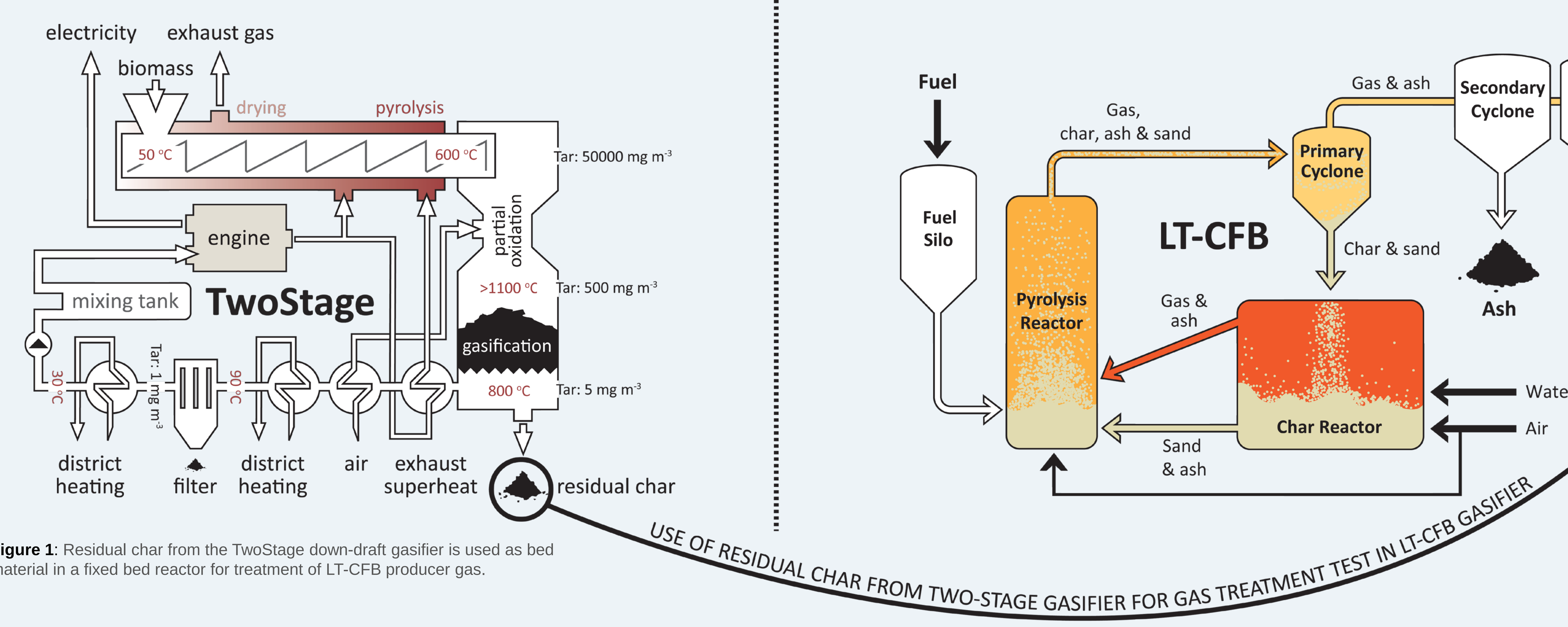

Figure 1: Residual char from the TwoStage down-draft gasifier is used as bed material in a fixed bed reactor for treatment of LT-CFB producer gas.

Figure 2: Residual gasification char from TwoStage process (fresh GB).

TwoStage gasifier (Viking)

Staged, fixed bed gasifier with maximum process temperature ≈ 1100 °C, suitable for low-ash biomass feedstock (wood chips). Produces an almost tar-free producer gas and a solid char residue with substantial soil enhancement potential [3].

Low Temperature Circulating Fluidized Bed gasifier (LT-CFB)

Staged, fluid bed gasifier with maximum process temperature ≈ 750 °C, suitable for conversion of straw and other ashes-rich feedstocks. The tar load in producer gas is high (up to 30 g/Nm^3). An effective reforming of tar is necessary to use the producer gas in gas engines, fuel cells and biofuel synthesis.

Gas treatment tests (test A and B)

Fresh GB (≈ 300 g) was added to a test reactor for gas treatment in two separate tests. In both cases, the test reactor was heated and maintained at 800 ˚C and flushed with LT-CFB producer gas for 2 hours. During test A, a small air flow was injected above the char bed ($\lambda \approx 0.3$), for partial oxidation of tar. During test B, on the contrary, no air was added. After the tests, the char beds were cooled down under N_2 atmosphere and then collected for analysis
.

Result highlights

Elemental Composition (CHNS)

Table 1: Elemental composition results (VarioEL III, Elementar Analysensysteme GmbH, Germany). Analysis performed at TU Berlin, Institute of Energy Engineering.

	C	N	H	S	H/C
	wt%	wt%	wt%	wt%	mol/mol
Fresh GB	87.6	0.1	0.63	0.04	0.09
Spent GB, test A	90.9	0.53	0.22	7.35	0.03
Spent GB, test B	94.5	0.61	0.22	2.04	0.03

BET surface analysis

Table 3: Results obtained through nitrogen gas sorption at 77 K (Nova 2200, Quantachrome instruments, USA). Analysis performed at TU Berlin, Institute of Energy Engineering.

	BET specific surface area	DFT pore volume
	m^2/g	cm^3/g
Fresh GB	1254	0.79
Spent GB, test A	234	0.18
Spent GB, test B	281	0.18

Polycyclic Aromatic Hydrocarbons (PAHs) contamination

Table 2: Results obtained through Soxhlet extraction (toluene) following DIN EN 15527. Analysis performed by Eurofins Umwelt laboratories, Germany.

	Naphthal.	Acenaphthyl.	Phenanthr.	Anthrac.	Fluoranth.	Pyr.	Total 16 EPA-PAH
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Fresh GB	8.2	1.2	0.9	0.1	0.2	0.2	10.8
Spent GB, test A	1.2	<0.1	0.2	<0.1	<0.1	<0.1	1.4
Spent GB, test B	1.0	<0.1	0.3	<0.1	<0.1	<0.1	1.3

Conclusion

Gasification char has promising characteristics for gas treatment and soil application for carbon sequestration purposes. When fresh GB is used for producer gas treatment at 800˚C for 2 hours, the following effects are observed:

- PAHs contamination decreases
- BET specific surface area decreases
- DFT pore volume decreases
- Carbon content increases

Specific surface area and porosity were found to decrease during gas treatment; nonetheless spent chars maintained acceptable surface properties. In addition, the PAHs contamination was found to decrease below the limit for premium grade biochar [6]. The carbon recalcitrance is expected to be higher for spent chars, as they contain soot black carbon derived from vapor phase tar. This form of carbon is considered as particularly stable [7]. The PAHs contamination assessment suggests that gas treatment application of GB may make it safer for soil application and carbon sequestration.

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